Cross–comparison of AIRS Cloud Products with ARM and A-train Measurements

by

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Cloud pictures courtesy of australiansevereweather.com

Outline

➢ **How valid are the AIRS V4 cloud fields?**

➢ **Focus on upper level CTP**
  ➢ **ARM TWP mm-wave cloud radar (Manus Island) and micropulse lidar (Nauru Island)**
  ➢ **AIRS is sensitive (statistically significant) to thin (and thick) cirrus**

➢ **AIRS CTP and Microwave Limb Sounder (MLS) IWC comparisons**
  ➢ **PDFs of AIRS and MODIS agree well…**
  ➢ **…but statistics conditional on MLS level, IWC threshold, AIRS ECF, etc.**

➢ **AIRS and MODIS: a "holistic" view**
  ➢ **Use CTP, ECF and T_s to explore consistency in retrievals**
  ➢ **Good agreement for high and opaque clouds**
  ➢ **Some issues within multilayer clouds and cloud edges**

➢ **Where to go from here?**

Checking the cloud top height between AIRS and Atmospheric Radiation Measurement (ARM) program observations
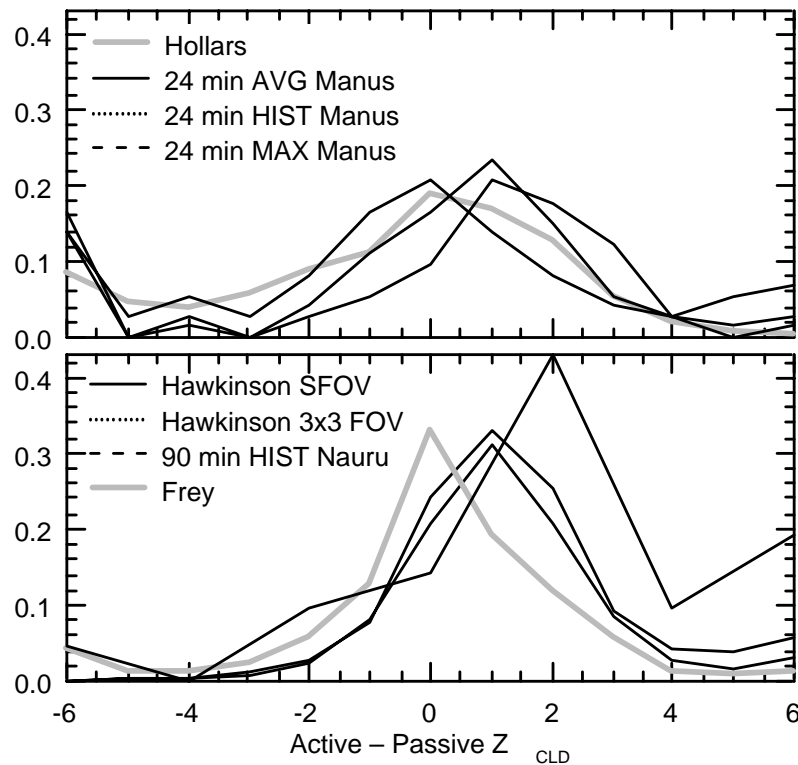
Frequency histogram of the agreement between an active and passive-derived Z_{CLD} obtained from several independent data sources. We compare ARM–AIRS to:

Top: ground-based MMCR with GMS-5 (*Hollars et al.,* 2004)

Bottom: aircraft lidar and the MODIS Airborne Simulator Z_{CLD} (*Frey et al.*, 1999), ground-based lidar+radar and GOES Z_{CLD} (*Hawkinson et al.*, 2005), and ground-based lidar and AIRS Z_{CLD}.

Kahn et al., 2006a

Three ARM Z_{CLD} averages

Five ECF bins

Radar at night

Three time averages

Radar at day

# of samples

Lidar at night

AIRS–ARM $\pm$ 1-σ (km)

Bold: significant @ 5%
Italic: significant @ 1%

| Location/Time	Time (min)	Height Method	$0. \le f < .05$	$.05 \le f < .15$	$.15 \le f < .5$	$.5 \le f < .85$	$.85 \le f < 1.0$
Manus/Night	–	–	N=13	N=9	N=21	N=16	N=16
	54	AVG	7.2 ± 7.0	2.1 ± 3.4	**0.4 ± 3.7**	*−0.1 ±1.5*	*0.7 ±1.8*
	126	AVG	7.1 ± 6.5	**1.8 ± 3.2**	**0.5 ± 3.6**	*−0.3 ±1.2*	*0.7 ±2.0*
	186	AVG	7.0 ± 6.5	**1.9 ± 3.0**	**0.4 ± 3.6**	*−0.4 ±1.3*	*0.6 ±2.0*
	54	HIST	7.1 ± 7.3	1.1 ± 5.1	*−0.9 ±3.4*	*−0.5 ±1.3*	*−0.1 ±1.7*
	126	HIST	4.9 ± 7.4	−0.5 ± 4.5	*−0.9 ±3.4*	*−1.2 ±1.0*	*−0.3 ±2.0*
	186	HIST	4.7 ± 7.5	−0.4 ± 4.1	*−1.0 ±3.3*	*−1.2 ±1.0*	*−0.2 ±2.0*
	54	MAX	5.3 ± 8.4	0.6 ± 4.9	*−2.2 ±4.0*	*−1.4 ±1.3*	*−0.8 ±1.9*
Manus/Day	–	–	N=21	N=12	N=16	N=12	N=16
	54	AVG	7.6 ± 5.6	6.3 ± 5.8	**1.2 ± 4.2**	*0.2 ±2.3*	*1.1 ±1.6*
	126	AVG	7.8 ± 5.6	4.5 ± 4.9	**1.3 ± 3.9**	*0.5 ±2.3*	*1.3 ±1.6*
	186	AVG	9.0 ± 5.0	4.4 ± 4.7	**1.5 ± 3.8**	*0.7 ±2.4*	*1.6 ±1.7*
	54	HIST	6.4 ± 8.8	5.4 ± 6.1	*−0.4 ±3.7*	*−0.1 ±2.7*	*0.5 ±1.6*
	126	HIST	3.7 ± 9.5	−1.0 ± 8.3	*−0.7 ± 3.8*	*−1.1 ±2.1*	*0.4 ±1.6*
	186	HIST	1.5 ± 7.8	−1.5 ± 8.5	*−0.8 ± 3.8*	*−1.1 ±2.1*	*0.4 ±1.5*
	54	MAX	4.8 ± 8.3	3.1 ± 8.1	*−0.7 ±3.8*	*−1.5 ±1.7*	*−0.2 ±1.4*
Nauru/Night	–	–	N=32	N=20	–	–	
	54	AVG	8.2 ± 6.1	*2.1 ±3.9*	–	–	–
	126	AVG	7.1 ± 6.1	*1.9 ±3.2*	–	–	–
	186	AVG	6.3 ± 5.4	*1.9 ±3.0*	–	–	–
	54	HIST	7.4 ± 7.3	*0.3 ±4.1*	–	–	–
	126	HIST	5.3 ± 7.8	*−0.7 ±3.7*	–	–	–
	186	HIST	3.0 ± 7.3	*−1.1 ±3.1*	–	–	–
	54	MAX	7.0 ± 7.5	*−0.5 ±4.5*	–	–	–

Kahn et al., 2006a

What about AIRS and MLS?

➢ **MLS is a passive microwave limb sounder**

➢ **Reports IWC at 11 altitudes from 46 to 316 hPa**

➢ **"Pixel" size roughly 165 × 7 × 3 km (along-track, cross-track, and vertical)**

➢ **Use nonzero IWC as a proxy to CTP**
  ➢ **Highest altitude of occurrence of IWC > 0 defined to be CTP**
  ➢ **Lowest values of IWC "similar" to clear sky**

➢ **Define AIRS CTP two ways:**
  ➢ **"High": lowest CTP from 3 nearest along-track**
  ➢ **"Avg": average CTP from 3 nearest along-track**

➢ **Different "views" of similar clouds**

Kahn et al., 2006a
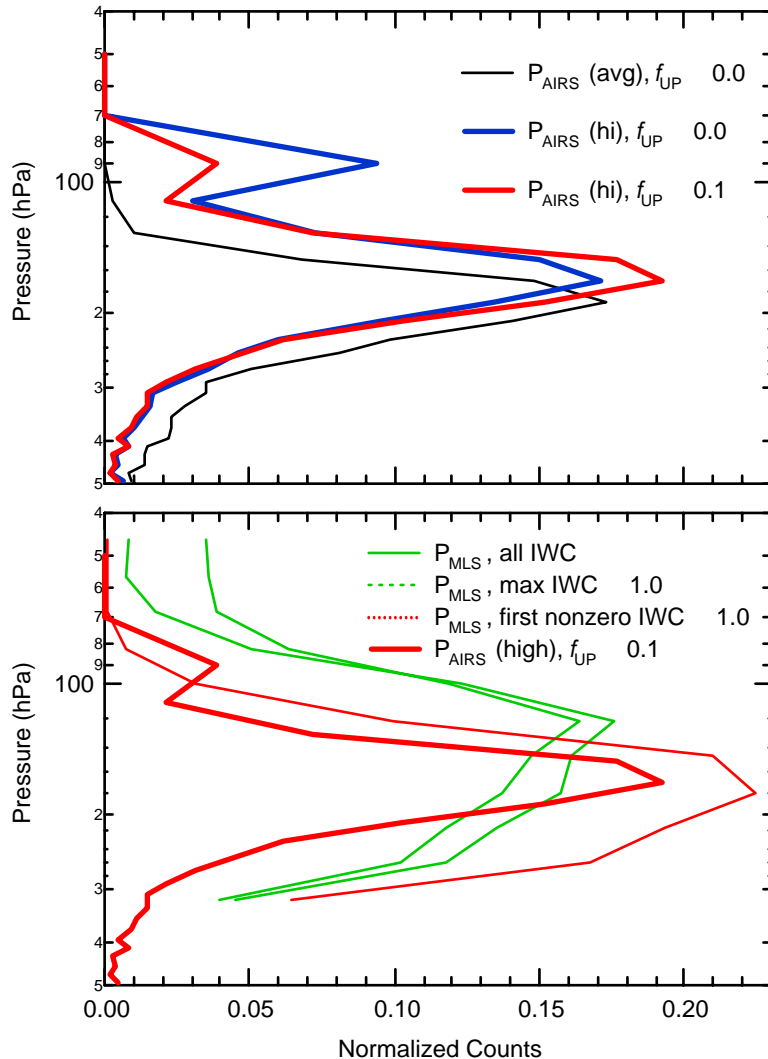
• Frequency of **coincident** AIRS and MLS P_{CLD}. The AIRS values in 20 hPa bins, and MLS reported at the MLS standard pressure levels.

• When we use all AIRS and MLS clouds, PDFs vary substantially

• When we exclude MLS *max* IWC < 1.0 mg m^{-3}, the agreement is similar

• When we exclude MLS first IWC < 1.0 mg m^{-3}, the agreement is *much improved*

Used ~20 days in January 2005 ± 30 deg latitude
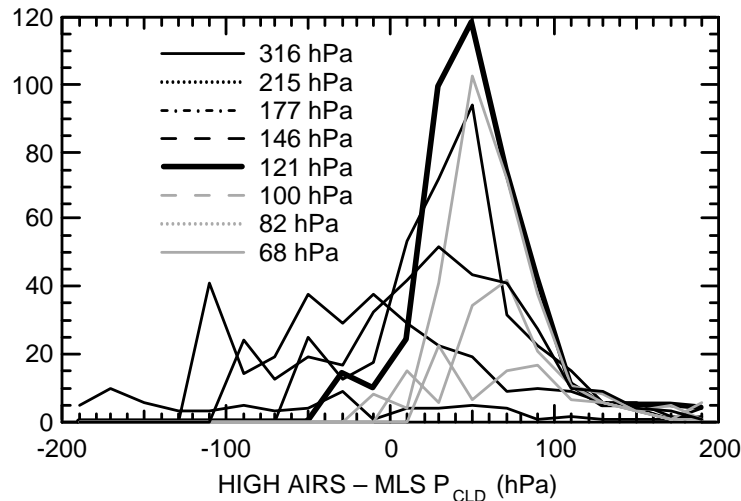
Difference between AIRS and MLS P_{CLD} per MLS pressure level: AIRS "hi" approach at top, "avg" approach at bottom

Some MLS pressure levels agree much more poorly than others
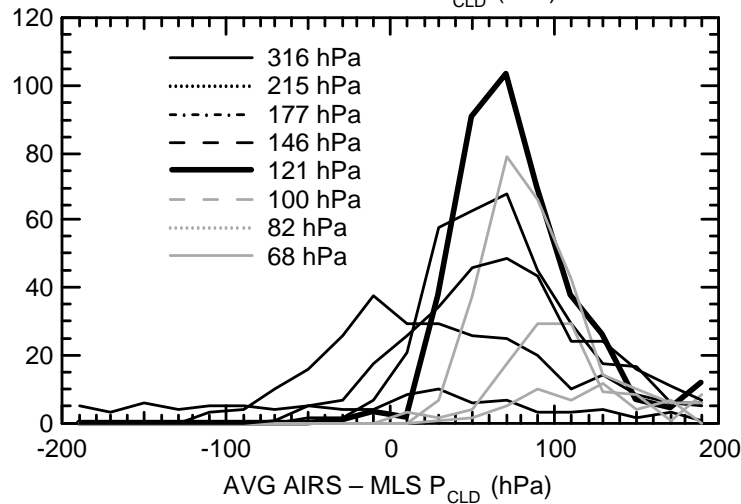
Lesson: the cloud morphology might look good after averaging, but individual match-ups can have large disagreement

Kahn et al., 2006a

Coincident AIRS and MODIS Cloud Products

- *Many* cloud products from AIRS and MODIS: stick to (operational) fundamental quantities ECF and CTP

- AIRS reports up to two cloud layers of CTP and ECF, MODIS only one

- MODIS reports ~ 5 km, while AIRS ~ 15 km for ECF, ~45 km for CTP

- Need to collocate AIRS and MODIS: not trivial

- How do we compare similar quantities from different instruments?
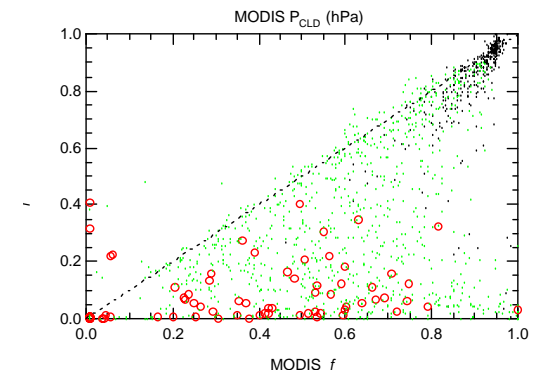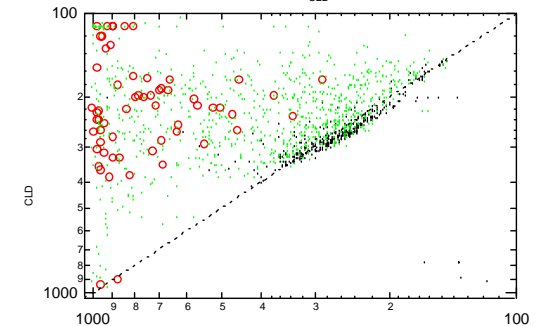
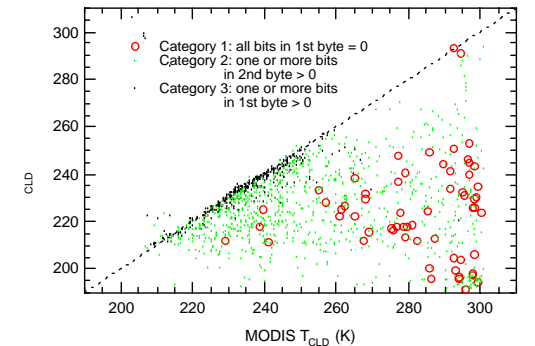# Consistency between AIRS and MODIS cloud products ?
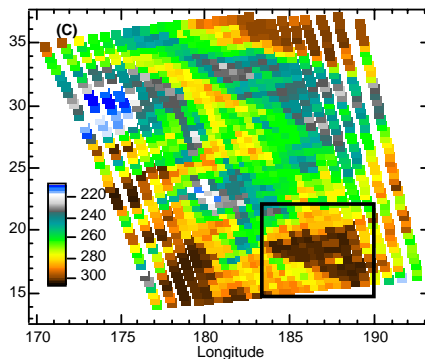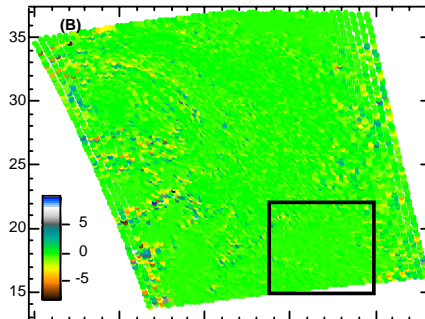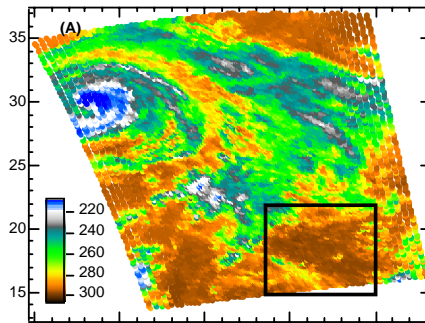
Left: September 6th, 2002, Granule 11, North-Central subtropical Pacific Ocean

Right: Agreement between AIRS and MODIS T_{CLD}, P_{CLD}, and f as a function of AIRS retrieval type.

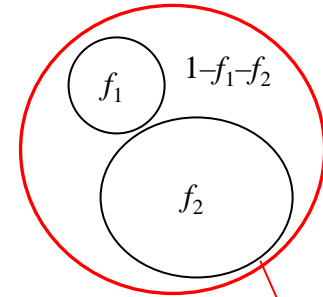**Bottom line:**

When clouds are thin and broken: ***bad agreement***.

When clouds are high and thick: ***good agreement***.

Kahn et al., 2006b

Should we think of cloud products in terms of "a whole" ?

$$BT_{AIRS} = f_1 \cdot T_1 + f_2 \cdot T_2 + (1 - f_1 - f_2) \cdot T_{sfc}$$

$$BT_{MODIS} = f_{cld} \cdot T_{cld} + (1 - f_{cld}) \cdot T_{sfc}$$

f_1 $1-f_1-f_2$

f_2

AIRS footprint

• "Re-build" BT from MODIS and AIRS cloud and surface products

• Replace Planck function by T of emitting layer or surface

• *First-order* means of comparison: does not guarantee that T or *f* agree individually , but shows if the "sum of the whole" agrees or not

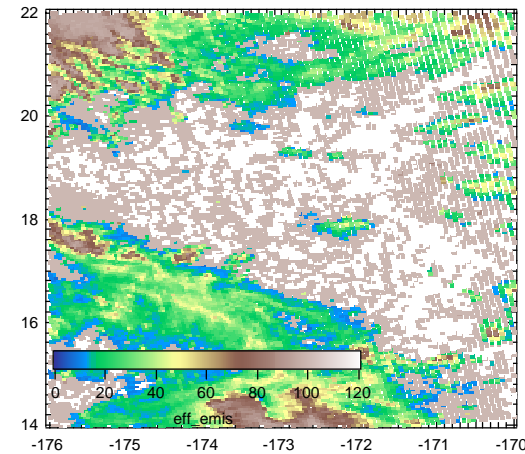• All products averaged to AMSU scale (~ 45 km)

Bottom line: A way to look at "consistency" of cloud products between AIRS and MODIS
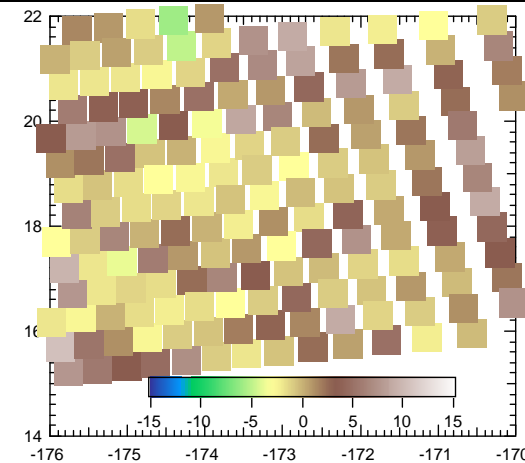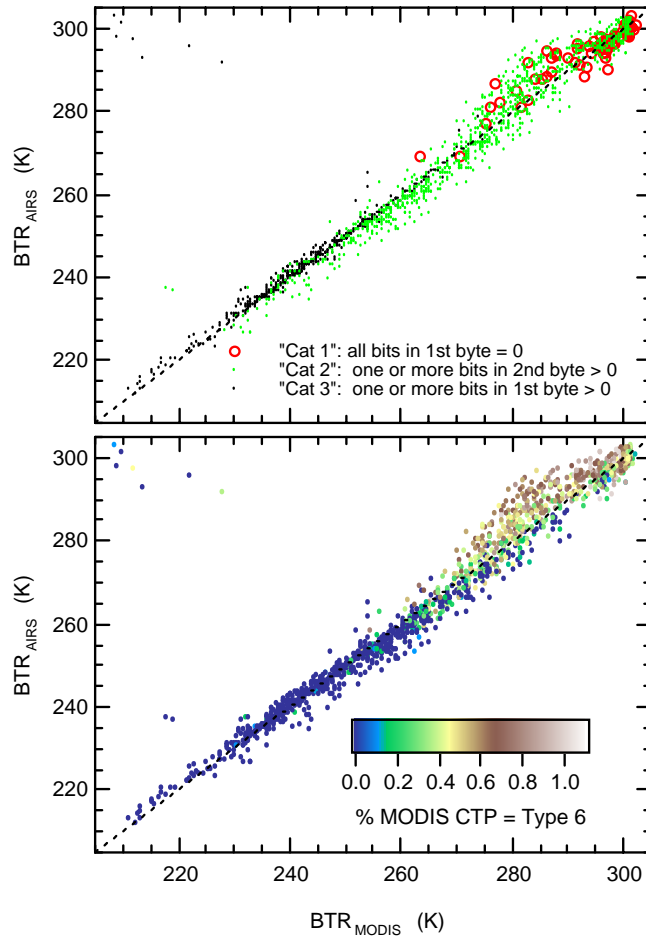
Kahn et al., 2006b

Should we think of cloud products in terms of "a whole" ?
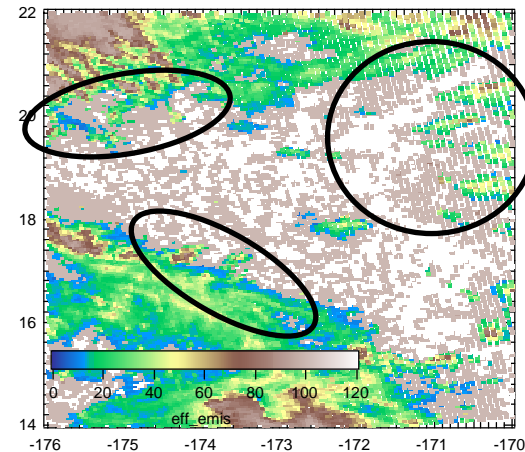

AIRS–MODIS BT_R
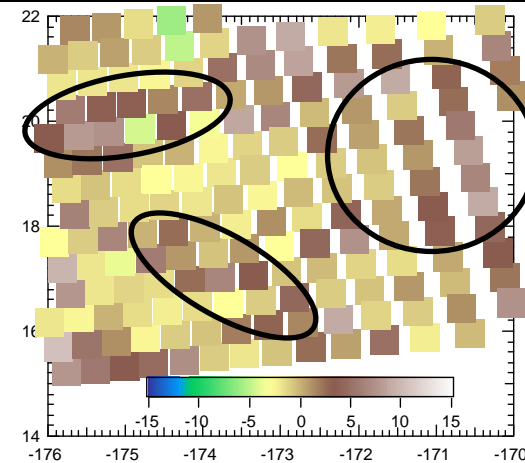
MODIS Effective Emissivity

Bottom line: BT_R is consistent, except near Ci edges – many possible reasons for disagreement

Kahn et al., 2006b

Should we think of cloud products in terms of "a whole" ?

AIRS–MODIS BT_R
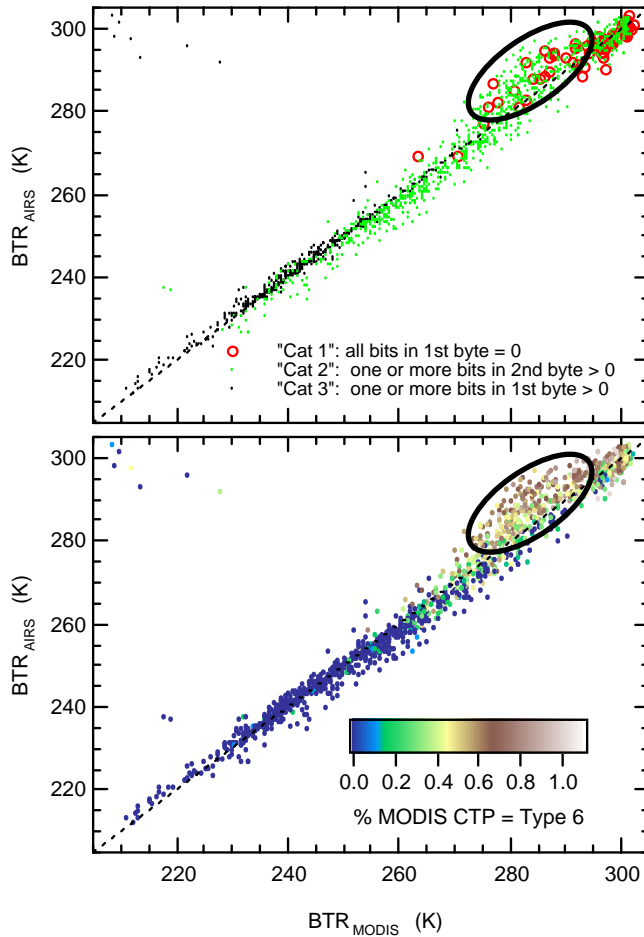
MODIS Effective Emissivity

Bottom line: BT_R is consistent, except near Ci edges – many possible reasons for disagreement

Kahn et al., 2006b

Why are there differences?

- MODIS and AIRS look at different clouds: collocation not perfect

- "Misplaced" MODIS cirrus as low cloud (MODIS cloud mask misses Ci w/ τ < 0.2–0.3)

- Multilayered clouds: errors in inferred cloud properties [*Baum and Wielicki* 1994]

- Method of averaging MODIS to AIRS footprint (lessons from AIRS/ARM comparisons)

- Nonlinearity in BT: misfits of MODIS and AIRS radiances, use of different channels

- Systematic errors in retrieval algorithms?

- 3-D IR effects [*Liou and Ou* 1979; *Harshvardhan and Weinman* 1982; *Cornet et al.* 2005]
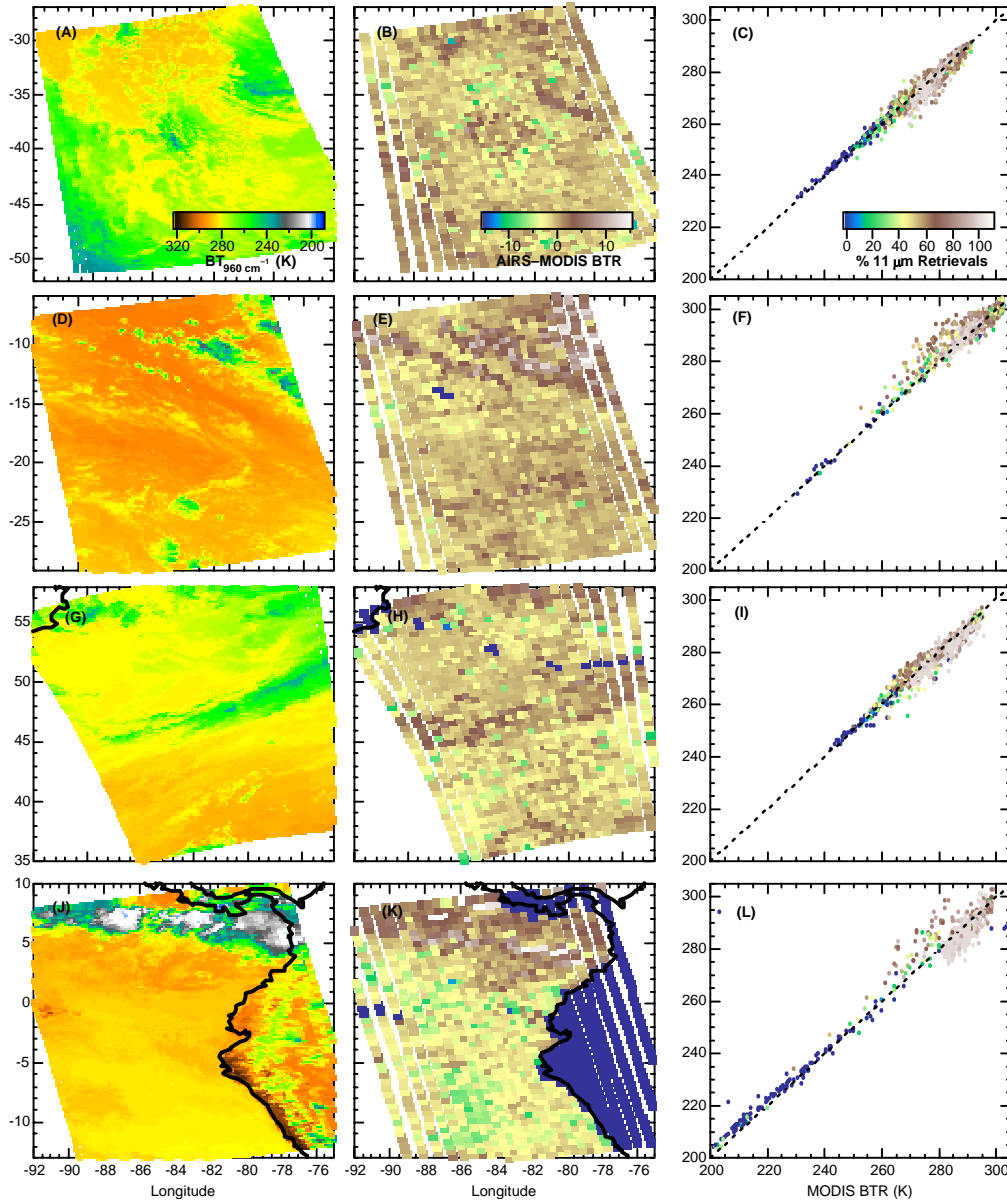
Midlatitude SH

Subtropical/tropical SH

Midlatitude NH

Equatorial East Pacific

Summary and Conclusions

- AIRS upper level CTP agrees well with ARM CTH, even for thin cirrus
    - Lidar comparisons imply AIRS CTP locates thin cirrus better than MMCR

- AIRS and MLS cloud placement similar when thin, tenuous cases discarded
    - However, height-dependence on agreement

- Holistic view of AIRS and MODIS more consistent than individual comparisons
    - Disagreement in reconstructed BT associated with cloud edges, multilayer clouds
    - Other possible reasons too

- Confidence in AIRS Version 4.0 clouds, despite large pixel size (~45 km CTP, ~15 km ECF)

- Useful for quantitative analyses, such as cirrus mapping and frequency, and τ and D_e retrievals